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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

LOS ANGELES MEETING

AT THE

UNIVERSITY OF CALIFORNIA

LOS ANGELES, CALIFORNIA

DECEMBER 12–13, 1930

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

The American Physical Society

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

LOS ANGELES MEETING, DECEMBER 12–13, 1930

The 167th regular meeting of the American Physical Society will be held in room 29 and later in room 137 of the Physics-Biology Building of the University of California at Los Angeles jointly with the Acoustical Society of America on Friday, December 12 and Saturday, December 13, 1930. The morning session of the Physical Society will begin at 10:00 o'clock on Friday, and the joint session with the Acoustical Society will occur at 2:00 o'clock on the same day. Titles and abstracts of the papers to be presented at this session will be given in the following pages. These abstracts have not been corrected by the authors. After correction they will be published in an early number of the Physical Review. Authors should send corrections to the Editor of the Physical Review at the University of Minnesota, Minneapolis, Minnesota.

Members will register on arrival in room 102 of the Physics-Biology Building, where programs and other information are available.

Visit to moving picture studios. A number of the moving picture studios will receive visitors from the Physical Society and Acoustical Society on Thursday afternoon, December 11, from 3:00 to 5:00 P.M., excursions to these studios to be arranged at the office in room 102 of the Physics-Biology Building.

Entertainment. On Friday at 12:30 there will be a joint luncheon for members of the Physical Society and Acoustical Society at a nearby country club or hotel, arrangements for which will be announced later. On Friday evening, December 12, at 7:00 o'clock a subscription dinner will be held for members of both societies at the Beverly Hills Hotel. The price will be $2.00 per plate. Members are asked to signify their intentions of attending when they register. It is probable that there will be a luncheon for members of both societies on Saturday noon followed by a visit to the sound studios. On their return from the sound studios the Acoustical Society will have a meeting at 3:00 P.M. in room 29, Physics-Biology Building. The Physical

Society will meet at 2:00 P.M. following the luncheon in order to complete their program.

Accommodations. *The Roosevelt Hotel*, 7006 Hollywood Boulevard has, been designated as hotel headquarters for the Acoustical Society. Rates $4.00–$5.00 a day for single room with bath, and $6.00–$7.00 a day for double room with bath. There is a 30 minute bus service to the University from this hotel from 8:00 A.M. to 10:00 P.M. Automobile service between hotel and University is being arranged for members of the Acoustical Society. Other hotels are:

Beverly Hills Hotel, 1201 Sunset Boulevard, Beverly Hills. Ten minutes by bus from the campus, rates: single rooms $3.00 per day, double rooms $5.00 per day, American plan $7.00 per day per person. A quiet, dignified hotel.

Miramar Hotel, Wilshire Boulevard and Ocean Front, Santa Monica. A quiet hotel on Pacific Palisades having a view of the ocean. Distant 20 minutes by bus from campus, and has 20 minute bus service. Rates: $3.00 per day for single room and $5.00 per day for double room (twin beds).

Schedules of bus service between these hotels and the campus may be had at the registration desk or at the Co-op. and at the hotels. For the following hotels ask for printed schedule.

Roosevelt Hotel	Hollywood - University - Santa Monica - Ocean Park motor coach line.
Beverly Hills Hotel	Beverly Boulevard motor coach line.
Miramar Hotel	Hollywood-University-Santa Monica-Ocean Park, or Wilshire Boulevard coach line.

Transportation from railroad station and Los Angeles business district. The Southern Pacific Railroad Station in Los Angeles is about seven blocks from the electric terminal at Fifth and Hill Streets. It can be reached by electric tram, D car, on foot, or by taxi. From this station a bus leaves hourly for the University campus at Westwood, and is labelled Castellammare Beach Bus. More frequent service (20 minutes) is had on the Wilshire Boulevard busses, changing busses to a local line for the campus at Westwood Village. The campus at Westwood is fifteen miles from the center of Los Angeles, and taxi service to either the campus or to the hotels is excessive. A schedule of bus service from Fifth and Hill is given below.

Daily except Saturday and Sunday

Lv. Fifth and Hill	6.10	6.29	6.45	6.54	7.00	7.10	7.07	7.17	7.27
Ar. Westwood	6.56	7.15	7.31	7.40	7.46	7.53	7.59	8.09	8.19
Lv. Fifth and Hill	7.37	7.47	7.53	7.57	8.07	8.17	8.37	8.57	9.17
Ar. Westwood	8.29	8.39	8.45	8.49	8.59	9.09	9.29	9.49	10.09
Lv. Fifth and Hill	9.37	9.57	10.17	10.37	10.57	11.17	11.37	11.57	12.17
Ar. Westwood	10.29	10.49	11.09	11.29	11.49	12.09	12.29	12.49	1.09
Lv. Fifth and Hill	12.37	12.57	1.06	1.18	1.26	1.32	1.42	1.52	2.02
Ar. Westwood	1.29	1.49	1.58	2.10	2.18	2.28	2.38	2.48	2.58
Lv. Fifth and Hill	2.12	2.22	2.32	2.42	2.52	3.02	3.12	3.31	3.49
Ar. Westwood	3.08	3.18	3.28	3.38	3.48	3.58	4.08	4.27	4.45

Lv. Fifth and Hill	4.07	4.25	4.37	4.51	5.07	5.24	5.45	6.03	6.18
Ar. Westwood	5.03	5.21	5.35	5.49	6.05	6.22	6.43	7.01	7.16
Lv. Fifth and Hill	6.42	7.10	7.40	8.15	8.35	9.15	9.35	9.55	10.10
Ar. Westwood	7.37	8.05	8.35	9.08	9.30	10.04	10.26	10.45	11.05
Lv. Fifth and Hill	10.45	11.15							
Ar. Westwood	11.35	12.05							

Saturdays Only

Lv. Fifth and Hill	6.10	6.30	6.45	7.00	7.02	7.15	7.25	7.35	7.47
Ar. Westwood	6.56	7.16	7.31	7.46	7.54	8.07	8.18	8.27	8.39
Lv. Fifth and Hill	7.57	8.17	8.37	8.57	9.17	9.37	9.57	10.17	10.37
Ar. Westwood	8.49	9.09	9.29	9.49	10.09	10.29	10.49	11.09	11.29
Lv. Fifth and Hill	10.57	11.04	11.16	11.32	11.52	12.09	12.25	12.41	12.55
Ar. Westwood	11.49	11.59	12.11	12.27	12.47	1.04	1.20	1.36	1.50
Lv. Fifth and Hill	1.12	1.26	1.41	1.57	2.13	2.29	2.49	3.09	3.29
Ar. Westwood	2.07	2.21	2.36	2.52	3.08	3.24	3.44	4.04	4.24
Lv. Fifth and Hill	3.49	4.09	4.28	4.46	5.02	5.26	5.43	6.10	6.40
Ar. Westwood	4.44	5.04	5.23	5.41	5.57	6.21	6.38	7.01	7.37
Lv. Fifth and Hill	7.10	7.40	8.15	8.35	9.35	9.55	10.10	10.45	11.15
Ar. Westwood	8.05	8.35	9.10	9.30	10.25	10.45	11.05	11.35	12.05

Daily except Saturday and Sunday

Lv. Westwood	6.59	7.20	7.34	7.41	7.48	7.56	8.06	8.14	8.23
Ar. Fifth and Hill	7.52	8.15	8.29	8.36	8.43	8.51	9.01	9.09	9.18
Lv. Westwood	8.32	8.41	8.50	8.59	9.08	9.17	9.35	9.54	10.14
Ar. Fifth and Hill	9.27	9.36	9.45	9.54	10.03	10.12	10.30	10.49	11.09
Lv. Westwood	10.34	10.54	11.14	11.34	11.54	12.14	12.34	12.54	1.14
Ar. Fifth and Hill	11.29	11.49	12.09	12.29	12.49	1.09	1.29	1.49	2.09
Lv. Westwood	1.34	1.54	2.04	2.14	2.24	2.34	2.44	2.54	3.04
Ar. Fifth and Hill	2.29	2.49	2.59	3.09	3.19	3.29	3.39	3.49	3.59
Lv. Westwood	3.14	3.24	3.34	3.44	3.54	4.04	4.19	4.35	4.49
Ar. Fifth and Hill	4.09	4.19	4.29	4.39	4.51	5.01	5.16	5.32	5.46
Lv. Westwood	5.07	5.25	5.45	6.00	6.19	6.30	6.50	7.10	7.20
Ar. Fifth and Hill	5.58	6.16	6.36	6.51	7.07	7.21	7.41	8.01	8.11
Lv. Westwood	7.43	8.13	8.48	9.09	9.43	10.05	10.25	10.45	11.15
Ar. Fifth and Hill	8.36	9.06	9.38	9.58	10.38	10.58	11.13	11.33	12.03
Lv. Westwood	11.35	12.05							
Ar. Fifth and Hill	12.23	12.52							

Saturdays only

Lv. Westwood	6.57	7.23	7.39	7.48	7.57	8.15	8.24	8.33	8.47
Ar. Fifth and Hill	7.52	8.18	8.34	8.43	8.52	9.10	9.18	9.27	9.41
Lv. Westwood	8.56	9.14	9.34	9.54	10.14	10.34	10.54	11.14	11.34
Ar. Fifth and Hill	9.50	10.08	10.28	10.48	11.08	11.28	11.48	12.08	12.28
Lv. Westwood	11.54	12.05	12.13	12.32	12.48	1.04	1.24	1.40	1.56
Ar. Fifth and Hill	12.48	12.59	1.07	1.26	1.42	1.58	2.18	2.34	2.50
Lv. Westwood	2.12	2.28	2.44	3.04	3.22	3.38	3.54	4.15	4.34
Ar. Fifth and Hill	3.06	3.22	3.38	3.58	4.16	4.32	4.48	5.09	5.28
Lv. Westwood	4.50	5.08	5.26	5.44	6.04	6.23	6.45	7.10	7.27
Ar. Fifth and Hill	5.44	6.02	6.17	6.35	6.55	7.14	7.36	8.01	8.21
Lv. Westwood	7.55	8.25	9.00	9.20	9.40	10.15	10.35	10.55	11.25
Ar. Fifth and Hill	8.51	9.21	9.58	10.18	10.38	11.13	11.33	11.48	12.03
Lv. Westwood	11.55								
Ar. Fifth and Hill	12.51								

CALENDAR

Thursday, December 11

3:00– 5:00. Excursions to studios.

Friday, December 12

10:00–12:30. American Physical Society, regular session room 29, Physics-Biology Building.

9:30–12:30. Acoustical Society of America, regular session room 137, Physics-Biology Building.

12:30– 2:00. Joint luncheon, place to be announced later.

2:00– 5:00. Joint meeting of American Physical Society and Acoustical Society of America, room 29, Physics-Biology Building.

7:00. Subscription dinner, Beverly Hills Hotel, for Physical and Acoustical Societies.

Saturday, December 13

10:00–12:30. Physical Society, regular session, room 29, Physics-Biology Building.

9:30–12:30. Acoustical Society, regular session room 137, Physics-Biology Building.

12:30– 1:30. Luncheon, place to be designated later.

1:30– 3:00. Visit of Acoustical Society to sound studios.

2:00– 5:00. Physical Society, regular session room 137, Physics-Biology Building.

3:00– 5:00. Acoustical Society meeting, room 29, Physics-Biology Building.

Other meetings for the current season are as follows:

168. Annual meeting, Cleveland, December 30–31, 1930.
169. February 27–28, 1931, New York.
170. April (Date not yet determined), Washington.
171. June 16–20, 1931, Pasadena.

FRIDAY DECEMBER 12, 1930, 2:00 P.M.
ROOM 29 PHYSICS-BIOLOGY BUILDING
JOINT SESSION AMERICAN PHYSICAL SOCIETY AND ACOUSTICAL SOCIETY OF AMERICA

1. **Acoustics of Music Rooms.** VERN O. KNUDSEN, University of California at Los Angeles.
2. **Loudness, Its Definition, Measurement and Computation.** HARVEY FLETCHER, Bell Telephone Laboratories.
3. **Sound Rays as Extremals.** HARRY BATEMAN, California Institute of Technology.
4. **Problems of Open Air Acoustics Affecting Fog Signals.** H. W. RHODES, U. S. Lighthouse Service, San Francisco.
5. **Acoustical Range Finding of Airplanes and Submarines.** LEO P. DELSASSO, University of California at Los Angeles.

PROGRAM

FRIDAY MORNING, DECEMBER 12, 10:00–12:00

1. Optical constants of CS_2-gasoline mixtures, at approximately 20° C, over the whole concentration range. L. E. DODD, *University of California at Los Angeles.*—Optical constants, particularly n_D and dispersion values, are obtained with a refractometer of the Abbé type, having heatable prisms. The gasoline used is of the commercial high-test type, and the CS_2 is commercial.

2. Metastable molecules and active nitrogen. JOSEPH KAPLAN. *University of California at Los Angeles.*—Strong uncondensed discharges through mixtures of nitrogen and mercury vapour at pressures of about 5 cm, yielded spectra of the first positive group of nitrogen with intensity distribution remarkably similar to that observed in the nitrogen afterglow. The bands originating on the B_7 and B_9 levels were strongly enhanced whereas in active nitrogen the bands arising on B_6, B_{10}, B_{11} and B_{12} are the unusually intense ones. The difference C_0-A_0 in nitrogen is almost equal to the energy of the mercury atom in the 2^3P_1 level and the difference C_0-A_1 equals the energy of the 2^3P_0 state of mercury. Thus collisions of the second kind between nitrogen molecules in the C_0 or C_1 levels (which are plentiful in the discharge) and Hg atoms, would account for a high concentration of metastable nitrogen molecules in the A_0 and A_1 levels. A second method for producing metastable molecules in these levels arises from the fact that the X_{18} and X_{19} levels of N_2 agree almost exactly with the 2^3P_0 and 2^3P_1 levels of Hg. An accumulation of nitrogen molecules in these levels would yield a large number of metastable N_2 molecules and nitrogen atoms in the electric discharge. The relationship of this experiment to the auroral spectrum is discussed.

3. The ultraviolet band system of sulfur monoxide, a $^3\Sigma\rightarrow{}^3\Sigma$ transition. EMMET V. MARTIN AND F. A. JENKINS, *University of California.*—The SO bands discovered by Henri (Jour. Phys. Rad. **10,** 81, (1929)) in the region λλ2500–3500 have been photographed in the first order of the 15-foot Rowland grating. The source was a quartz discharge tube containing SO_2 at 30 mm pressure, actuated by a condensed discharge with spark gap and inductance. The spectrum appears to be closely analogous to the Schumann-Runge system of O_2 (Holtgreven and Dieke, Ann. d. Physik **3,** 937, (1929)). The characteristic structure found there for a $^3\Sigma\rightarrow{}^3\Sigma$ transition is clearly shown in the SO bands. Thus each band contains only P and R branches, in each of which the lines split into narrow doublets with increasing K. The short-wave component is stronger (in contrast to O_2) and at the highest K values this in turn splits in two, giving clearly resolved triplets. The components of these are of equal intensity and correspond to the triplet levels $J=K+1$, K, and $K-1$. This structure is best shown in the bands with $v'=0$. In the $v'=1$ progression, the P and R branches are usually almost superposed, and irregularities are present which must be ascribed to a number of small perturbations in the rotational levels of the upper state.

4. Zeeman effect of the hyperfine structure in Thallium II and III. R. F. BACHER (*National Research Fellow*), *California Institute of Technology.*—The positions and intensities of the Zeeman components of lines which have hyperfine structure can be calculated for intermediate field strengths. This has been done for several of the lines of the first and second spark spectra of thallium which have recently been studied experimentally by McLennan and Durnford. (Roy. Soc. Proc. **A129,** 48, (1930)) The line ($6s7s\ ^3S_1-6s7p\ ^3P_2$) λ5949 of Tl II and the line ($7s\ ^2S_{1/2}-7p\ ^2P_{1\,1/2}$) λ4110 of Tl III have been studied particularly. For field strengths between 20 and 25 kilogauss the former shows an intermediate type of Zeeman effect while the latter shows an incomplete Paschen-Back effect. A comparison shows that there is agreement between the calculated results and experiment, although the observed patterns do not seem to be completely resolved.

5. Preliminary report on an investigation of the spectrum of columbium. ARTHUR S. KING, *Mount Wilson Observatory* AND WILLIAM F. MEGGERS, *Bureau of Standards*.—Analyses of the structures of the very rich spectra of neutral and ionized columbium, although partly successful (Meggers, Jour. Washington Academy of Science **14**, 442, (1924) Meggers and Kiess, J.O.S.A. and R.S.I. **12**, 431, (1926)), could not be extended without new descriptive data and improved wave-lengths. A comparison of the furnace spectrum with the arc and spark spectra has therefore been made, and has resulted in the temperature classification of 650 of the stronger lines. The wave-lengths of more than 4000 lines have been measured in the arc and spark spectra from λ2640 to λ6900. Tested by "constant differences" between wave-numbers, the average error appears to be less than one part per million, or about 1/10 of the tolerance on values heretofore available. A feature of special interest is the large proportion of columbium lines showing hyperfine structure. Such lines are plentiful in the spectra of both neutral and ionized columbium, and are not confined to groups requiring high excitation. Much variety in width of patterns is found. While some lines are more than one wave-number in width, the components are so closely spaced that high resolution will be required for a study of their structure.

6. New data on the absorption bands of atmospheric oxygen. H. D. BABCOCK AND W. P. HOGE, *Mount Wilson Observatory*.—From numerous new spectrograms and further measurements of earlier plates, revised wave-lengths are derived for 382 oxygen band lines. Significant differences from previous Mount Wilson results occur only for lines most difficult to measure. Principal lines in the *A* band, strong in solar spectrum, were observed with interferometers as fine sharp lines in 30 meters of air. Solar grating spectra of dispersion ranging from 0.8 to 0.12A per mm and resolving power 200,000 to 400,000 were used for other bands. Due to the variety of instrumental equipment available and amount of measurement done, observational errors were reduced to approximately 0.001A for the best material. Improved resolution has thus been obtained and band structure extended to higher rotational states. Accurate wave-lengths are determined for 241 lines in 5 bands of $O^{16}-O^{16}$, 116 lines in 2 bands of $O^{16}-O^{18}$, and 25 lines in 1 band of $O^{16}-O^{17}$. For the *A* band our results differ from those of Badger and Mecke by amounts far exceeding our observational errors. Following a rigorous theoretical study of the isotope effect in band spectra by Birge, a full discussion of the new data will appear in a joint paper giving precise relative masses of O^{16} and O^{18}.

7. Precision determination of atomic mass ratios from band spectra. RAYMOND T. BIRGE, *University of California*.—With sufficiently extensive data available, it is preferable to calculate directly the band constants of two isotopic molecules (such as $O^{16}\cdot O^{16}$ and $O^{18}\cdot O^{16}$), rather than to use the customary method of calculating each line of $O^{18}\cdot O^{16}$ from the observed constants of $O^{18}\cdot O^{16}$. Each pair of constants involves ρ to some power, and $mass_{18}=mass_{16}/(2\rho^2-1)$. Two important relations are $\omega_e{}'=\rho\omega_e$ (vibrational isotope effect), and $B_e{}'=\rho^2 B_e$ (rotational effect). These relations should be theoretically correct to the extent that the electric field is identical for the two molecules (as indicated by the proportional size of the electronic isotope effect). Other relations such as $\alpha_e{}'=\rho^3\alpha_e$, and $x_e{}'=\rho x_e$ should be correct only to the extent that the old mechanics is true (as contrasted with the new mechanics). An independent calculation of $\alpha_e{}'$ (or of α_e) requires data from two bands, and $x_e{}'$ (or x_e) requires three bands. These constants (α_e and x_e) are needed for the extrapolation to B_e and ω_e from the observed B_v and ω_v. A precision method for calculating B_v has been published, and a similar method for obtaining ω_v is now devised. This method is being applied to new data on oxygen obtained by Babcock and Hoge.

8. The rotational raman effect in carbon dioxide. W. V. HOUSTON AND C. M. LEWIS, *California Institute of Technology*.—By the use of a large, water-cooled mercury arc, and a highly polished reflector, we have been able to reduce the exposure time necessary to secure a spectrum of the light scattered by gases. This has made it possible to use a large spectrograph and to resolve the rotational Raman band of carbon dioxide. The results indicate that, for rotation about an axis perpendicular to the line joining the two oxygen atoms, the spectrum is similar to that of O_2, and indicates a moment of inertia of about 7×10^{-39}. The rotational quantum number jumps by two units, which shows that there are no Q branches in the transitions from

the ground state to the upper electronic state which is active in producing the Raman spectrum. Alternate lines are very weak, and it seems probable that they are missing altogether. There is a slight indication of another very much smaller moment of inertia.

9. A determination of e/m from the Zeeman effect. J. S. CAMPBELL AND W. V. HOUSTON, *California Institute of Technology.*—Values of e/m have been obtained from the Zeeman separations of the Cd line λ6439 and the Zn line λ6362. Magnetic fields up to 7500 gauss are produced in a solenoid giving less than 0.1% departure from uniform field strength over a length of 6 cm at the center. The current-field ratio of the solenoid is evaluated by balancing its field against those of single layer standard solenoids. Evaporation of Zn and Cd in the short (6 cm) positive column of a helium discharge at the center of the solenoid gives the desired lines, the Zeeman patterns of which are photographed with a Fabry-Perot interferometer crossed by a prism spectrograph. Measurement of the separations at orders of interference in the neighborhood of 100,000 gives the following values of e/m: Zn λ6362, seven exposures: 1.7577×10^7 e.m. units per gram with a mean deviation of ± 0.0005. Cd λ6439, eleven exposures: 1.7573×10^7 with the mean deviation ± 0.0015.

10. Emission and Absorption spectra of CaF. A. HARVEY (*Commonwealth Fund Fellow*) *University of California.*—High dispersion spectrograms of these bands have been studied for the purpose of (1) searching for possible evidence of the isotopes of Ca, (2) interpreting the appearance of the two visible systems in terms of the known structure types of $^2\pi \rightarrow {}^2\Sigma$ and $^2\Sigma \rightarrow {}^2\Sigma$ transitions. The observed heads and their intensity distribution have been accounted for in detail in terms of the above transitions, by an approximate evaluation of the molecular constants. Due to the near equality of these constants in the upper and lower states, the heads are in general formed at very high J values. This results in two important modifications in passing from emission to absorption. (1) Certain heads disappear, or are greatly weakened, due to the lower temperature; (2) the intensity maximum in a sequence is shifted toward earlier members. The remarkable appearance of the $^2\Sigma^{(v)} \rightarrow {}^2\Sigma^{(v)}$ sequence in absorption is a natural consequence of these factors, as are also the presence of only one set of heads in the $^2\pi_{3/2}{}^{(v+1)} \rightarrow {}^2\Sigma^{(v)}$ sequence, and of a new set—shaded toward the red—in $^2\pi_{1/2}{}^{(v+1)} \rightarrow {}^2\Sigma^{(v)}$, which had previously been thought to be absent. Support for these conclusions has been found in a study of the analogous SrF spectrum.

SATURDAY MORNING, DECEMBER 13, 9:30–12:30

11. An apparatus for the evaporation of various materials in vacuo. JOHN STRONG AND C. HAWLEY CARTWRIGHT, *California Institute of Technology.*—The evaporation process is much easier and requires less time than sputtering and permits the deposition of many more materials. Moreover, the thickness of the deposited film can be brought under more delicate control. The method is useful for making fine reflecting mirrors of many metals and these can be protected from tarnishing by depositing onto them an extremely thin transparent film of some non-metal such as quartz. Charcoal cooled with liquid air was satisfactory for maintaining the necessary high vacuum. The metallic elements deposited were Al, Sb, Be, Bi, Ca, Cr, Co, Cu, Au, Fe, Pb, Mg, Mn, Ni, Se, Ag, Te, Sn, and Zn. Some alloys may be deposited, such as speculum metal. Some non-metals deposited were quartz, fluorite, the alkali halides, and silver chloride. These materials may be deposited on any surface that is not affected by the high vacuum, such as glass, metal, paper, cloth, rubber, and nitrocellulose.

12. Effects of phase and time shifts on binaural sensation of direction. A. W. NYE AND A. K. STEUNENBERG, *University of Southern California.*—Experiments were made to test the effect of phase and time shifts of pure tones on the binaural sensation of direction. Separately generated tones were led to two ears via independent telephone receivers. Sources consisted of a metal disk rotated by a variable speed motor. Periphery was cut in sine wave and located in front of slits through which light passed to photoelectric cells and associated amplifiers. Two slits were used, one being adjustable so that any desired location with respect to the phase of the sine wave could be obtained. Means for interrupting the two light beams independently were provided. Between 180 dv and 725 dv, 27 observers consistently judged

direction as that of the leading phase, with tendency toward greater angle shift at higher frequencies. Interrupted tones gave effect of sound origin on side where sound first arrived. Phase shift exaggerated this if in same direction; if opposed, the temporal ruled first and effect shifted later in favor of phase.

13. On the measurement of galvanometer or radiometer deflections which are ordinarily masked by Brownian movement. SINCLAIR SMITH, *Mount Wilson Observatory.*—Under certain conditions the following technique enables one to measure galvanometer or radiometer deflections which are small compared to the mean amplitude due to Brownian motion. A beam of light from the instrument mirror is brought to a focus on a photographic film and the intensity of the light is reduced to such a value that a relatively long time interval, Δt, is required to record the image on the film. Δt should be several times the average "period" of the Brownian excursions.

When a measurement is made, the instrument is set at the zero position and the recording lamp is turned on for a time Δt. The "effect" is then allowed to act, the photographic film is given a displacement, and when the instrument has had time to reach full deflection, the light is again turned on for a time Δt. The actual deflection is determined later on a comparator. If the damping factor of the instrument, and Δt are properly chosen, and the instrument is free from drift, the photographic image builds up in such a way that it has a sharp maximum making possible excellent comparator settings.

14. Ionization of helium, neon, and argon by alkali positive ions. RICHARD M. SUTTON AND J. CARLISLE MOUZON, *California Institute of Technology.*—A more extensive investigation of the ionizing properties of several positive ions from Kunsman sources has been carried forward by a method previously reported (Phys. Rev. **33**, 364, (1929) and **35**, 694, (1930)). Evidence of ionization of the three lighter noble gases by alkali positive ions from lithium to caesium has been found, setting in at accelerating potentials in the neighborhood of 150 volts and increasing steadily to the highest potential used, 750 volts. Comparison of the relative efficiencies of the process indicates that, for a particular gas, ionization is produced most intensely by that alkali ion which lies closest to the gas in atomic number; i.e., Li^+ ions in helium, Na^+ ions in neon, and K^+ ions in argon. Moreover, the maximum of ionization increases markedly with the atomic weight of gas used, being greatest for argon. Similar results have been determined by Dr. Otto Beeck, (Ann. d. Physik in publication) using a magnetic analysis method well adapted to the purpose. Experiments are now in progress to determine whether mass or electron configuration plays the predominating part in the process. Neither energy nor velocity of the positive ions, or ballistic transfer considerations appear sufficient at present to account for the striking results obtained.

15. Nuclear scattering of high velocity electrons. H. VICTOR NEHER, *California Institute of Technology.*—A homogeneous beam of fast electrons, two millimeters in diameter and equal to a current of 1.5 (10^{-6}) amperes, is allowed to fall normally upon a thin foil. The thickness of the foil is such that single scattering predominates in the angular range through which the scattered electrons are collected. Secondary electrons up to one-fourth the voltage of the primary beam are eliminated by interposing an absorbing foil of known stopping power which allows 98–99% of the electrons scattered by nuclei to pass through. The majority of the secondary electrons from the interposed foil on the collector side are stopped by a retarding potential of 1500 volts. Scattering is obtained as a function of various angles between which the electrons are collected, thickness of foil and voltage of the primary beam. A range of voltage from 45 to 145 K.V. is used. Results show that for aluminum, the absolute value for scattering is from 25 to 50% lower than that obtained by previous workers in this field, and from 20 to 30% higher than the predicted value of wave mechanics with spin and relativity corrections. The large experimental value may be due to radiative effects, which would tend to increase the scattering at larger angles and which have not been incorporated into the theories of scattering to date.

16. The probability law governing ionization by electron impact in mercury vapor. CURTIS R. HAUPT (*Introduced by Ernest O. Lawrence*) *University of California.*—In order to detect any fine structure in the ionization probability function, such as that observed by

Lawrence in mercury vapor, it is necessary to employ electron beams of a high degree of homogeneity. The method of magnetic separation, with Faraday cylinder type of ionization chamber used by Lawrence is open to the objection that magnetic orientation of the atoms or spurious effects arising from electron reflection at the walls of the ionizing chamber might account for the results. With an electron gun type of ionization tube which eliminated the above sources of error, and which permitted realization of a rather high degree of homogeneity in the electron beam, the ultra-ionization potentials discovered by Lawrence were completely checked. In addition, his probability law was verified to within the limits of experimental error and new ionization potentials in the mercury atom were found at 12.3; 12.45; 12.85 and 13.2 volts. On account of striking numerical agreements with spectroscopic data, it is suggested that these new critical potentials are connected with the ionization of metastable mercury atoms. This suggestion is supported by the current-voltage characteristics of the tube itself.

17. Photoelectric properties of atomic layers of potassium on a silver surface. JAMES J. BRADY, *University of California*, (*Introduced by Ernest O. Lawrence*).—In this work atomic layers of potassium were deposited on a silvered glass surface which was maintained at liquid air temperature. By means of a specially designed vacuum tube a well defined beam of potassium atoms could be obtained. The film thickness was determined from the vapor pressure of the heated potassium and the length of time taken for the deposit. The pressure, in turn, was determined from the table given by H. Rowe (Phil. Mag. **3,** 540 (1927)); the temperature of the heated potassium being determined by means of a thermocouple. Spectral distribution curves were taken for various thicknesses of film. The threshold was found to be at a longer wavelength for a monomolecular layer (3×10^{15} atoms per cm^2) than for any other thickness. The maximum emission, however, occurs at about 5 atomic layers. The curves approach the wavelength axis quite steeply for thicknesses of a monomolecular layer or less, in contrast to an asymptotic approach for a greater number of layers. The curves are identical for thicknesses greater than 12 atomic layers.

18. A Visual study of the initial stages of spark breakdown in air. FRANK G. DUNNINGTON, *University of California*. (*Introduced by Ernest O. Lawrence*).—With the Kerr cell electro-optical shutter it has been found possible to observe visually the breakdown of a single spark at any stage of its development. This provides a means of determining the initial regions of breakdown (as indicated by their luminosity) and the manner in which the breakdown progresses. At atmospheric pressure in an initially homogeneous field a faint diffuse path first appears connecting the electrodes. A bright spot then develops at the cathode and a conducting filament guilds out from it meeting a filament of later origin which has come from the anode. The entire process requires slightly over 10^{-8} sec. for a gap of 6 mm. Initially non-homogeneous fields give various types of breakdown, the initial breakdown region being in the central part of the gap in some cases instead of at the cathode. Space charges that can produce field distortion sufficient to cause localized regions of luminosity can form within 5×10^{-9} sec. In general the effect of moisture in the air increases the field distortion. The low capacity nitrobenzene Kerr cells developed for this study have a time of cut-off less than 10^{-9} sec. Increasing the capacity of the Kerr cell, keeping other factors the same, causes a retardation in cut-off (2.5 times the capacity gave a delay of 2×10^{-9} sec.).

19. The mobility of aged ions in air. N. E. BRADBURY, *University of California*. (*Introduced by L. B. Loeb*).—Investigations by Marshall (Phys. Rev. **34,** 618, (1929)) and Luhr (Phys. Rev. **35,** 1394, (1930)) on the recombination of ions produced by intense x-radiation has shown that the coefficient of recombination decreases continuously as the age of the ions increases after the sharp initial drop due to non-random distribution. An investigation by Luhr and Bradbury (Phys. Rev, **35,** 1398, (1930)) using the same source of ionization and ionization chamber on the mobilities of air ions aged over the same lengths of time using a Langevin method of low resolving power gave negative results. In the present investigations the value of the mobility of air ions produced in pure air by x-rays has been studied for ions between the ages of 0.04 sec and 1 sec. An absolute method devised by Tyndall and Grindley (Proc. Roy. Soc., **110,** 341, (1926)) is used which consists essentially of the application of an intermittent

alternating field to parallel plates immersed in a gas. The frequency of the alternations may be varied by means of a commutator system, and at a critical frequency a maximum occurs in the electometer current-frequency curve from which the mobility may be calculated. For *new* ions of age less than 0.08 sec the average of all determinations gives 2.21 cm/sec/volt/cm for the mobility of the negative ion and 1.59 cm/sec/volt/cm for the positive ion in agreement with absolute values obtained by Loeb and Tyndall and Grindley. By varying the constants of the commutator system the ions could be aged for varying lengths of time. Mobilities measured after ageing show a decrease whose magnitude increases with increasing age until values 10 percent lower than the normal are reached at ages of 1 sec. This effect can be partially correlated with the decrease in the coefficient of recombination.

20. The collision cross-section of thallium atoms for slow electrons. ROBERT B. BRODE, *University of California.*—The average collision cross-section of thallium atoms has been measured by sending a beam of electrons through thallium vapor and observing the decrease in intensity of the beam as a function of the pressure of the vapor. From these data the absorption coefficient, α, i.e. the sum of the collision cross-sections of the atoms in one cubic centimeter of the gas at 1 mm pressure, has been calculated. α plotted as a function of the velocity of the electrons shows a sharp minimum at 1.4 volts, $\alpha=15$, a maximum at 4.5 volts, $\alpha=51$, and then sloping off gradually with $\alpha=31$ at 25 volts and $\alpha=20$ at 100 volts. The thallium atom appears to have about $\frac{1}{2}$ of the effective collision cross-section of a mercury atom for 100 volt electrons. The numerical magnitude of α depends on the density of the thallium vapor which is calculated from the vapor pressure, using the equation, $T \log p = 8890 + 8.55\ T$. However, the data from which this equation was obtained can not be relied upon sufficiently to attach much significance to the difference in size of the Hg and Tl atoms as measured by their effective collision cross-sections. The precision with which the relative values of the absorption coefficients can be observed is independent of this uncertainty of the vapor pressure.

21. The production of high speed mercury ions without the use of high voltages. ERNEST O. LAWRENCE AND DAVID H. SLOAN, *University of California.*—For studies of collision processes involving high speed charged particles we are developing methods for the production of such high speed particles which do not require high voltages. A method for obtaining high speed protons was described at the September meeting of the National Academy of Science (Science **72,** 376, (1930)). For heavier ions we are using a succession of cylinders arranged in line and connected alternately to the inductance of an oscillatory circuit. High frequency voltages of proper amount and frequency accelerate successively ions traveling through the tubes. This method has been demonstrated in principle by R. Wideroe (Ark. F. Elektrot, **21,** 387, (1929)). Our initial experimental arrangement has yielded with little difficulty mercury ions of about 90,000 volt electrons energy using a high frequency exciting voltage of 11,000 volts at a wavelength of 70 meters. A tube capable of much greater voltage amplification is under construction.

SATURDAY AFTERNOON, DECEMBER 13, 2:00–5:00

22. Polarization of light scattered by H-atoms. BORIS PODOLSKY, *Los Angeles.*—In the solution of the dispersion problem, if the size of the atom is not neglected in comparison with the wave-length of light, the scattered light is found to have a component of the electric vector in the direction of propagation of the incident light. The relative intensity of the two components of scattered light, when observed at right angles to the direction of propagation of the incident light, is computed as a function of the frequency.

23. Selection rules and the angular momentum of light quanta. J. R. OPPENHEIMER, *California Institute of Technology.*—One may deduce the selection rules for angular momentum from the conservation laws for angular momentum by applying these laws to the system atom plus light quantum field. This is done most readily by taking a linear Hamiltonian for light quanta: this gives an angular momentum for the quanta which is in part orbital, and in part a spin momentum which is determined by the polarization of the quanta. In this way one obtains very simply the probability of a violation of the selection rules by the multipole radiation of the atom.

24. On the theory of the scattering of high velocity electrons in hydrogen. HUGH C. WOLFE (*National Research Fellow*), *California Institute of Technology.*—The scattering of electrons by free protons and by free electrons at rest is investigated, using the Dirac transition probability method. The wave functions used are Darwin's solutions for a free particle of Dirac's linear wave equation. The interaction energy is the perturbation causing transitions. Random distribution of spins is assumed. The relativistic variation of mass with velocity is taken into account. It is found that spin and retardation effects are negligible in the protonic scattering, Mott's formula for nuclear scattering being therefore the best. For the scattering by electrons, three interactions are treated (1) electrostatic, (2) the Gaunt-Eddington form, including spin, (3) the Breit form, including also retardation. The resulting formulae are different from each other and from Mott's non-relativistic formula by terms of order $(v/c)^2$, differing in symmetry as well as in absolute magnitude. These formulae apply to scattering in hydrogen for velocities high enough to treat the proton and electron in the atom as independent but not high enough to require keeping higher powers of (v/c), a good experimental region being from 125,000 to 200,000 volts.

25. Dependence of Compton line breadth on scattering angle with the multicrystal spectrograph. JESSE W. M. DUMOND AND HARRY KIRKPATRICK, *California Institute of Technology.*—Jauncey, Wentzel and Dumond have each attributed the observed breadth of the Compton line to the velocities possessed initially by the electrons in the scattering body. To test the corrections of this assumption the authors have obtained photographic spectrograms of the Compton effect with the multicrystal spectrograph with extremely homogeneous scattering angle for three scattering angles $63\frac{1}{2}°$, 90°, 155° (inhomogenity less than one degree). Dumond has shown (Phys. Rev. **33**, 643, (1929)) that the Compton line breadth for a given scattering material and primary wave-length should increase with the scattering angle if the initial electron velocities cause the breadth. If $\Delta\lambda$ is the line breadth at say half maximum and θ the scattering angle then, according to Dumond's theory

$$\Delta\lambda = K \sin \tfrac{1}{2}\theta \text{ approximately.}$$

The spectrograms and microphotometer curves show an increase in breadth of the Compton shifted line in agreement with this formula. The Compton line breadths however appear to be larger than those observed with the double spectrometer by Bearden and Gingrich and by the balanced filter method of Ross. Further investigations are in progress to determine if possible the cause of this discrepancy.

26. Intensity of monochromatic x-rays reflected from platinum in the neighborhood of the critical angle. HIRAM W. EDWARDS, *University of California at Los Angeles.*—X-radiation from a water-cooled tungsten tube, operated at 50,000 volts, is made monochromatic by reflection from a calcite crystal. The monochromatic ray ($\lambda = 0.69$A) is reflected from a platinum sputtered mirror at various small glancing angles in the region of the critical angle. The intensity of the ray reflected from platinum is measured by an ionization chamber and string electrometer. Experimental values of intensity are found to agree closely with those calculated by the Fresnel classical formula as extended by Thibaud.

27. The natural widths of some x-ray lines in the L-spectrum of uranium. JOHN H. WILLIAMS, *University of California.*—The double x-ray spectrometer, with previously examined crystals, has been used to measure the natural widths of the more intense lines in the *L*-spectrum of uranium at 50 kv. Most of the widths are observed in the (1, 1) anti-parallel position. Geometric corrections arising from the vertical spread of the beam have been applied. A broad focus tube has been used in order to insure a true measure of the width. These widths have been found to be greater than those observed for the MoK_α doublet. The half widths at half maximum of the following lines are: UL_{α_1} (in 3 orders), 0.44 *X.U.*; UL_{α_2}, 0.50 *X.U.*; UL_{β_1}, 0.32 *X.U.*; UL_{β_2}, 0.38 *X.U.*; UL_{γ_1}, 0.25 *X.U.* Possible correlations with the transitions involved are suggested.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session after the completion of the regular program for the session.

1. Note on the statistics of nuclei. J. R. OPPENHEIMER, *California Institute of Technology.*—Consider two similar stable configurations, each with p protons and e electrons. It is then possible to give a simple purely analytical proof that the exclusion principle for the electrons and protons requires that the total wave function for the two configurations be symmetric or antisymmetric in the coordinates of the center of gravity of the two configurations, according to whether p plus e is even or odd. To establish this it is necessary to assume that the configurations are so stably bound that the interaction between the two systems does not appreciably distort their internal motion. This condition, which may be made precise, is necessary and sufficient for the validity of the theorem.